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ON THE POSSIBLE ORIGIN OF METEOROID GENERATING ASTEROID ORBITS

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A mechanism to replenish the Apollo and Amor groups by resonant asteroid-orbit transformation is suggested.

As is well known, the semi-major axes of resonant orbits oscillate periodicially about a value a corresponding to the exact commensurability with eccentricities oscillating out of phase. The periods and amplitudes of such librations depend on the initial value of eccentricity e, longitude of the perihelion π and on the initial position of the asteroid and Jupiter. We suggested a characteristic parameter M^* (KAZANTSEV and SHERBAUM, 1984) which connects the position of the asteroid on the orbit with the position of its line of apsides vis-a-vis Jupiter. Numerically it equals $\Delta\sigma$ - the oscillation amplitude of libration argument introduced by SCHUBART (1968). The value of M^* (or $\Delta\sigma$) defines the size of the libration for a and e. This characteristic parameter changes from 0° to 180°: for $M^* = 0$ the libration amplitude of a is minimum, for $M^* = 180°$ it is maximum. According to SHARLJE, (1966) $\Delta\sigma$ is an integral of motion in the circular, limited three-body problem. It is clear that in the most general case, $\Delta\sigma$ is not constant. However, numerical calculations carried out by us as well as by different authors have revealed no changes of $\Delta\sigma$. According to SCHUBART's (1982) results, $\Delta\sigma$ remains invariable for the interval of up to 10^4 years. Besides short-period librations, the eccentricities undergo long-period changes with the same period as that of the perihelion longitude. The rates of these changes (de/dt and $d\pi/dt$) are determined by the value of M^*. The dependences de/dt (M^*) and $d\pi/dt$ (M^*) are reproduced in Fig. 1 for the commensurability 1/3, $e_o = 0,3$ for different values of π. These were obtained using numerical calculations for the interval of 500 years. By dividing these dependences into pairs, the function $|de/d\pi|(M^*)$ for each value of π is obtained (Fig. 2). The gap of these functions in the region of $M^* = 100° - 120°$ is explained by the existence of orbits for which secular changes of the perihelion longitude practically equal zero whereas secular changes of eccentricities differ appreciably from zero. This peculiarity is true of all commensurabilities regardless of the values for e and π. In other words, the eccentricities of the orbits in the range of $\Delta\sigma$ from 100° to 120° can reach the largest values. Since the value $\Delta\sigma$ changes, even though very slowly, all the resonant orbits will, sooner or later, find themselves in favorable conditions for reaching large eccentricities. Some of these asteroids could become members of the Apollo and Amor groups.

Among the numbered minor planets there are only two known asteroids with orbits librating in commensurability 1/3 with Jupiter. These are Alinda (887) and Quetzalcoatl (1915). Their orbital elements are e = 0,55, π = 100° and e = 0,58 and π = 150° respectively. The changes of the elements given in Fig. 3 were obtained using our calculations of their evolutions. The mean rate of change of π for Alinda is nearly zero, the eccentricity increasing only slightly. This is the real confirmation both of the existence for a break in the function $|de/d\pi|(M^*)$ and the reaching of large eccentricities by resonant orbits. The orbit of the minor planet, judging by its characteristics, is in the very center of the gap.

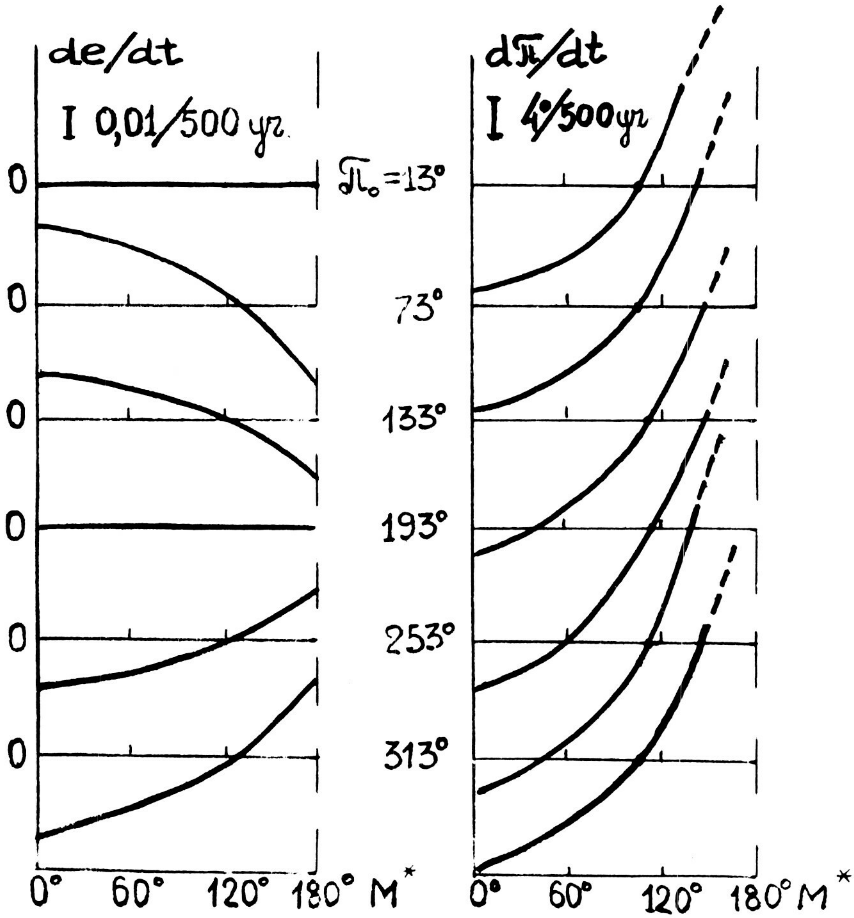

Fig. 1 Velocity dependences of M* for long-period changes of eccentricity (de/dt) and longitude of perihelion (dπ/dt) having different π_o (a_o = - 2, 50 a.u., e_o = 0,3).

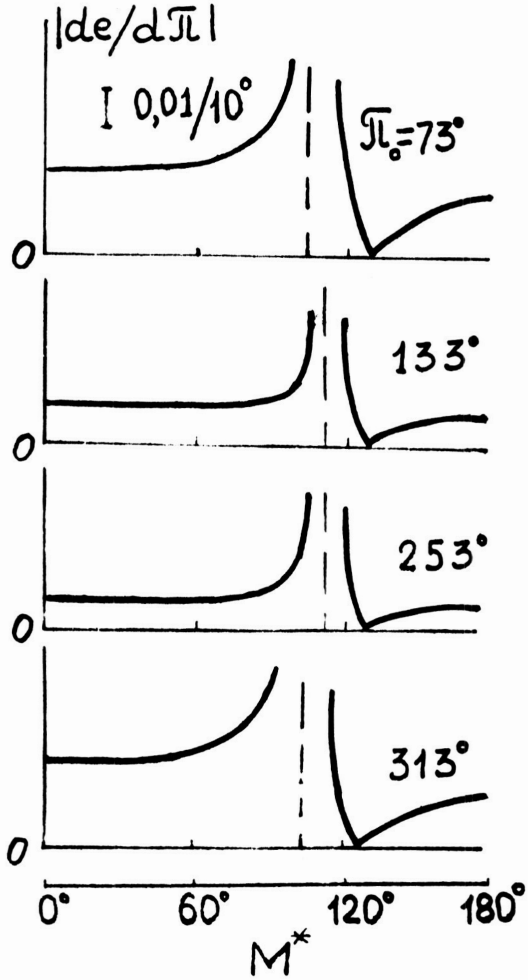

Fig. 2 Dependence $|de/d\pi|$ of M* for different π_o (a_o = 2,50 a.u. e_o = 0,3).

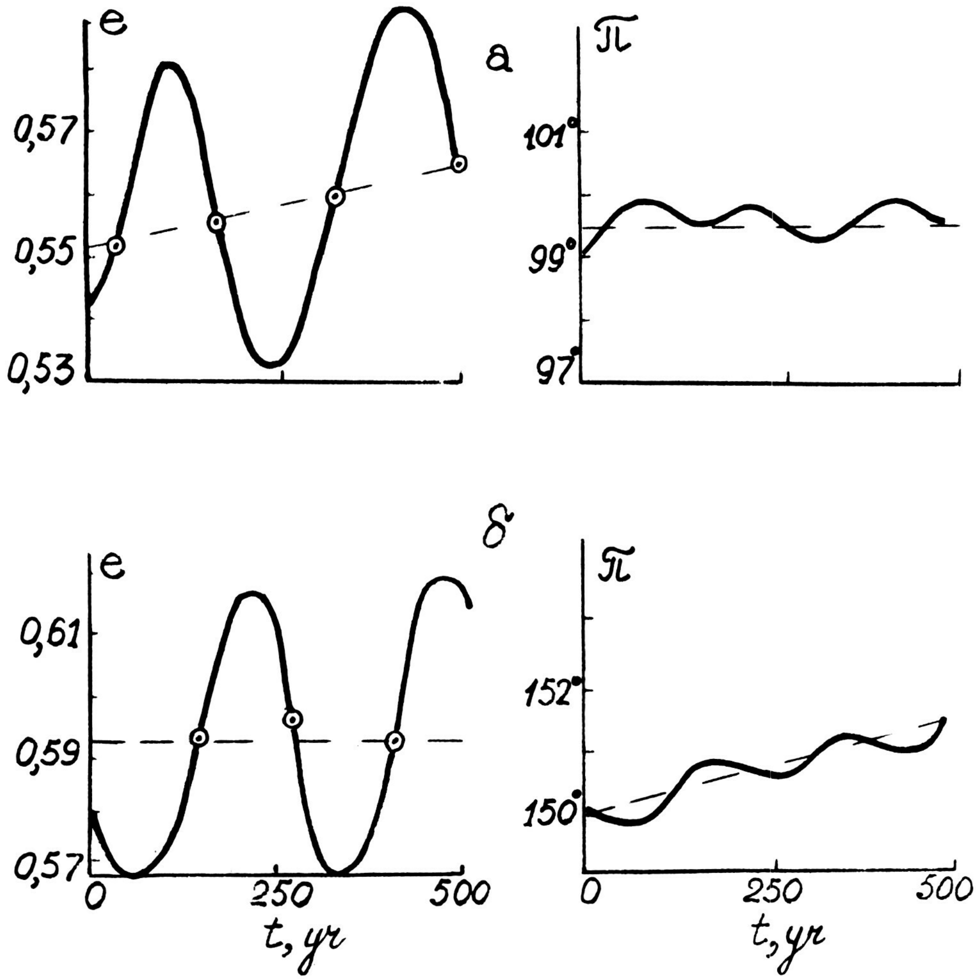

Fig. 3 Evolution of e and π elements for asteroid orbits: a - No. 887, b - No. 1915 (o - a = a_c).

The perihelion longitude of asteroid No. 1915 slightly increases (by nearly 1.5° in 500 years), the eccentricity practically not changing (this is perhaps explained by π being so close to 193°, the value at which the condition $de/dt = 0$ is fulfilled). The characteristic parameter M^* for this orbit is 130° which is at a distance of about 10° from the gap of the function $|de/d\pi|(M^*)$ with $e = 0{,}6$, $\pi = 164°$ (Fig. 4). (Out of our numerous model orbits, these are the nearest to orbit elements of the minor planet No. 1915).

In MARSDEN's (1970) work, the results of calculations are given for an orbital evolution of the asteroids No. 887 and Nol 1915. The calculations were carried out using a more exact program than ours for a time interval of 1,400 years.

According to both Marsden's and our calculations, the asteroid orbit is at a distance of no more than 8° from the gap of the function $|de/d\pi|(M^*)$. Consequently both orbits have just the very values of M^* which, according to our conclusions, ensure large eccentricities (the range of definition of M^* is 180°). The majority of Apollo and Amor asteroid orbits have the value $a < 2{,}5$ a.u. Large eccentricities of these orbits can be reached, in principle, by consideration of cases other than 1/3 resonances with Jupiter.

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